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Predicting olivine formation environments using machine learning and implications for magmatic sulfide prospecting

Shengchao Xue[1], Yunyun Niu[2,*], Zhuosen Yao[3], Luyang Wang[1], Xiaohao Zhang[2], and Qingfei Wang[1,†]

[1]State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China
[2]School of Information Engineering, China University of Geosciences, Beijing 100083, China
[3]School of Earth Resources, China University of Geosciences, Wuhan 430074, China

Abstract

Global volcanic and plutonic olivines record the compositional characteristics and physicochemical conditions of the parental magmas. Thus, they have significant potential for use as petrogenetic discriminators of the olivine formation environment and prospecting indicators for potential host rocks of magmatic sulfide deposits. Several data visualization approaches have been proposed by researchers to determine olivine origins. However, they can only discriminate specific olivine populations and require the incorporation of trace elements for which data are lacking globally. In this study, a machine-learning method consisting of the random forest algorithm and the synthetic minority oversampling technique (SMOTE) is used to discriminate the crystallization environments of olivine and predict the sulfide potential of olivine-bearing mafic-ultramafic intrusions. We employ a global data set of 24 341 olivine samples from 12 environments to determine the contents of MgO, FeO, Ni, Ca, Mn, and Cr and the Fo number [100 × Mg/(Mg+Fe)]. The results indicate that the proposed method can classify olivine into genetically distinct populations and distinguish olivine derived from mineralized intrusions from that derived from sulfide-barren intrusions with high accuracies (higher than 99% on average). We develop a dimensionality reduction algorithm to visualize the olivine classifications using low-dimensional vectors and an olivine classifier (accessible at http://101.33.204.62:8080/olivine_web/main.html, China University of Geosciences, Beijing). The model is used successfully to identify the contributions of distinct sources to regional magmatism using olivines from the late Permian picrite and basalt along the western margin of the Yangtze block (SW China) and to predict the sulfide potential of the newly discovered Qixin mafic-ultramafic complex in the southern Central Asian Orogenic Belt (NW China). The findings suggest that the proposed approach enables the accurate identification of olivine origins in different formation environments and is a reliable indicator suitable for global Ni-Cu-platinum group element (PGE) exploration.

Keywords: Olivine chemistry, mineral formation environment, magmatic sulfide potential, formation environment classification, ore deposit prediction, machine learning